HEMOLYTIC POTENTIAL OF RAPID SPEED VARIATIONS IN THE HEARTMATE 3

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Introduction

The artificial pulse is a special feature introduced to enhance arterial pulsatility with the HeartMate 3 (HM3, Abbott Inc, Chicago, USA). The artificial pulse represents a periodic variation in the impeller speed, with a change of 4000 rpm in 0.35 seconds occurring every 2 seconds. Previous numerical studies have highlighted the importance of the artificial pulse in reducing the low-velocity regions, which may contribute to the low thrombogenicity of the HM3 [1-2]. However, the sudden variation in the speed introduces turbulent flow behavior, which is reflected in the elevated shear stress distribution inside the pump [1]. The aim of this study is to evaluate the impact of the artificial pulse on hemolysis in a hybrid mock circulatory loop.

Methods

We utilized an established hybrid mock circulatory loop [3] to evaluate the blood damage potential of HM3 under three operating conditions: artificial pulse mode, cardiac pulsatile mode, and constant speed mode. The nominal operating point of the HM3 was adjusted to 5600 rpm, and the same targeted mean flow rate of 4.25 L/min in all three conditions. Heparinized bovine blood was utilized for this study, with free hemoglobin (fHb) measured every 30-minutes and the conditions adjusted every 2 hours. Additional to hemolysis, the degradation/fragmentation of high molecular weight (HMW) von Willebrand Factor (vWF) multimers was analyzed for every 2 hours through gel electrophoresis and western blotting.

Results

Overall, six experiments were conducted for the hemolysis assessment with 12 measurements per experiment. The achieved mean flow rate was 4.25 ± 0.007 L/min, and the mean pressure head was 75.3 ± 0.08 mmHg (Figure 1). The calculated delta-free hemoglobin revealed no significant difference between the conditions ($p > 0.74$), with an NIH of 6.1 ± 0.09 mg/100L. The degradation of HMW vWF multimers was analyzed in 4 experiments with 4 samples each. Qualitative results showed a linear degradation in the multimers over a 6-hour period.

Discussion

In this study, we showed that the artificial pulse feature has no significant impact on hemolysis compared with continuous and pulsatile flow conditions in HM3. The similar delta fHb values between the three conditions reflect the relationship between shear stress and exposure time, which was globally similar among the three conditions. In detail, approximately 20% of the blood volume passing through the pump during one artificial pulse (0.5 Hz) was exposed to different levels of shear stresses. The combined effect of the volume of blood exposed to shear stress during low flow, due to the reduction in speed (0.15 s) and high flow, due to the increase in speed (0.2 s), together with the exposure time may balance each other out, resulting in a similar delta fHb comparing to continuous flow. On the other hand, the mean flow rate through the pump remains constant, resulting in no significant difference in the calculated NIH between the three conditions.

The observation on the vWF multimer showed qualitatively similar behavior in degradation between the conditions; a quantitative analysis is ongoing.

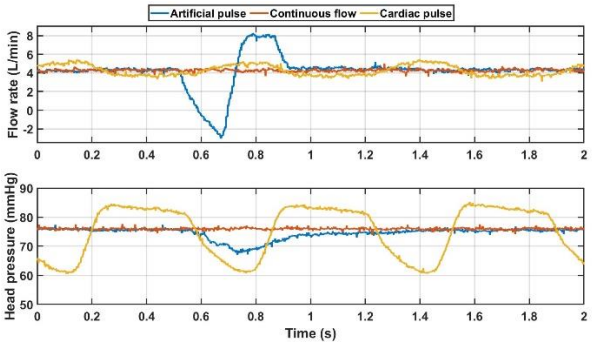

Figure 1: The measured flow rate and pressure head from the hybrid mock circulatory loop for the three operating conditions.

References

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